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Richard D. Robarts
Environment Canada
National Water Research Institute
11 Innovation Blvd.
Saskatoon, SKS7N 3H5 Canada
Fax: (306) 975-5143
E-mail: richard.robarts@ec.gc.ca

Contributions on a PC formatted disk, in any standard word processor or DOS (ASCII) text, or as e-mail attachments, will assist the Editor.

Returning to the Wild: Creating Lakes on Industrial Cutaway Peatlands in Ireland

By Tara Higgins

Ireland's extensive boglands have been intensively harvested for various peat products since the founding of the Peat Development Board, Bord na Móna, in 1946. As a result, the country will be home to in excess of 80,000 hectares of redundant, worked-out bogland, referred to as 'cutaway peatland,' by 2030. Bord na Móna first began investigating alternative uses for this land in the 1950s and 1960s. The research identified serious problems associated with the two traditional and economically attractive post-harvesting uses of commercial forestry and agricultural grassland; these included water-logging, nutrient deficiencies, weed invasion and soil subsidence (Egan, 1999).

In recent years, the focus in Ireland has shifted towards rehabilitating cutaway peatlands for wildlife conservation and public amenity uses. In fact, Bord na Móna now proposes to flood and revegetate 40,000 ha of its cutaway peatlands, resulting in the formation of a semi-natural wilderness mosaic extending throughout the Irish Midlands (Egan, 1998). The range of ensuing habitats will be diverse, encompassing numerous stands of shallow open water, some of which will be designated as angling lakes, large areas of marsh and fen, expansive tracts of naturally regenerating grassland, smaller pockets of scrub woodland and localised nuclei of regenerating sphagnum bog (Rowlands & Feehan, 2000). The scale of the proposal is vast, representing one of the largest habitat creation opportunities to emerge in Europe in modern times.

Lough Boora Parklands Project

A taste of what is to come in Ireland is exemplified in a pilot scheme called the Lough Boora Parklands. This is a 2,000 ha cutaway peatland rehabilitation project located in County Offaly in the heart of the Irish Midlands (07°43'W, 53°13'N), which is being viewed as a blueprint for the future large-scale development of integrated land-uses on Ireland's cutaway peatlands (Egan, 1999).

Within the Lough Boora Parklands, Bord na Móna has created 400 ha of experimental waterbodies since 1991, using a variety of construction approaches. Some lake creation projects involve a considerable level of on-site development work;

Photo 1: Aerial photograph of an Irish industrial cutaway peatland which has been flooded.

prior to flooding, most of the residual peat deposit is removed by land-moving machinery to create a lake basin, in the process exposing the underlying mineral sub-soils such as silty clays, glacial till soils, gravel and calcareous shell marl. Embankments are formed around the new lake basin using the excavated peat, artificial drainage channels are in-filled and the basin is allowed to flood to a depth of 1-2 m from a combination of precipitation, groundwater spring discharges and surface drainage (McNally, 1999). In some cases, water levels are supplemented by an introduced piped inflow diverted from a nearby natural stream. In deeper lakes designed specifically for angling purposes, pioneering aquatic plants and macroinvertebrate species are introduced to initiate and assist natural colonisation. The areas surrounding the lake are landscaped, seeded and planted with trees and pubic facilities such as walkways, picnic tables and bird hides are provided (Photo 2). Examples of lakes constructed using these approaches are Finnamore, Tumduff and Turraun (Table 1).

In more recent years, less site preparation has been conducted prior to flooding and lake creation projects have been concentrated on sites that are naturally low-lying (Photo 3). Peat excavation is minimal and sites are flooded to depths of about 1 m by simply blocking the network of drainage ditches that was constructed prior to the commencement of peat harvesting. Lakes, such as Clongawny (Table 1), created according to this strategy recolonised naturally with minimum human interference.

Photo 2: Bird hides, such as this one at Tumduff lake, are among the public amenities provided by Bord na Móna within the Lough Boora Parklands.

Limnological Characteristics

Individual cutaway lakes differ markedly in their water chemistry and trophic states, as the values presented in Table 2 illustrate. The current data were gathered during a 3-year study at the National University of Ireland, Galway, conducted between August 2001 and September 2004. Physicochemical differences reflect, to a large extent, the strategy adopted during the lake construction process, which determines the degree of peat removal, basin construction, hydrological manipulation and post-flooding management carried out.

The exposure of minerotrophic sediments such as alkaline fen peats, blue silty clays, and calcareous marls at Finnamore, Tumduff and Turraun, coupled with the presence at these sites of telluric hardwater influxes, resulted in high pH, high alkalinity and low to moderate colour. Clongawny, in contrast, was an acidic, poorly buffered, darkly stained lake. These properties, as expected, reflect the peaty nature of the lake substratum, which included deposits of highly humified sphagnum peat, coupled with the absence of hardwater inflows at the site, which was fed exclusively by precipitation and associated runoff from the surrounding actively-milled peatfields.

Nutrient concentrations in cutaway lakes are strongly influenced by catchment landuses (Higgins & Colleran, in press). In Finnamore lake, for example, the elevated mean dissolved inorganic nitrogen (DIN) concentrations reflect the presence of nitrate runoff from the lake catchments; the piped inflow at this site is diverted from a stream that drains intensively-grazed agricultural land. Such trends give a clear indication of the effect of stream water quality on cutaway lakes that receive piped surface inflows.

Based on their mean total phosphorus and chlorophyll-a data, both Finnamore and Tumduff are mesotrophic, Turraun is mesotrophic-eutrophic, and Clongawny is eutrophic-hypertrophic. The latter was strongly affected by phosphate-rich fertiliser runoff from adjacent coniferous forestry plantations (Higgins *et al.*, in press). Many industrial cutaway peatlands are particularly susceptible to phosphorus leaching due to their low content of chelating iron, aluminium, and carbonate ions and high rates of erosion caused by unconsolidated sediments and often low-lying topography (Renou *et al.*, 2000). Moreover, the absence of vegetation on recently abandoned cutaway peatland sites, such as Clongawny, removes an important biological buffering mechanism. Collectively, these abiotic and biotic characteristics make lakes created on bare, unconsolidated cutaway peatland, such as Clongawny, extremely vulnerable to nutrient runoff from the catchment area. The very strong response of the algal population in Clongawny to the increased phosphorus input was enhanced by a lack of top-down control by invertebrate grazers in the lake, reflecting both the young age of the lake and the paucity of vegetation at the site, which provides essential refugia and food for recolonising invertebrates in cutaway peatland lakes (O Connor *et al.*, 2000).

Lessons Learned

Lake creation on industrial cutaway peatland is a major post-harvesting land-use option in Ireland. A number of simple, cost-effective lessons can be learned from the existing experimental lakes within the Lough Boora Parklands, to ensure that the wildlife conservation and public amenity value of future cutaway peatland lakes is maximised.

- The current study demonstrated categorically the direct and indirect benefits of revegetating cutaway peatland designated for lake creation. Higher vegetation increases the sediment stability, thus reducing water column turbidity and nutrient recycling from the sediments; filters nutrient runoff from the catchment area; competes directly with algae for nutrients within lakes, thereby restricting algal biomass; provides habitat,

refuge and food availability for recolonising invertebrates and so increases algal losses by grazing. Natural plant recolonisation on cutaway peatlands intended for lake creation should be expedited by active management such as seeding and creating small changes in the surface elevation or texture of bare, uniform cutaway peatfields, which encourages natural plant establishment.

- Cutaway peatland lakes should be designed with an irregular shoreline, involving bays, inlets and island regions, in order to maximise habitat diversity. Lake shores should be gently sloping, to encourage the establishment of littoral aquatic plants. Removing sufficient peat to expose the inorganic subsoils is desirable, in order to both increase physicochemical variability and to enhance phosphorus losses by co-precipitation with carbonate. These measures will provide a diversity of microhabitats within individual lakes, in turn promoting higher biological diversity and species richness
- An integrated, holistic approach to planning that balances economic, practical and technical concerns needs to be adopted if the conservation value of cutaway peatlands is to be maximised. In particular, vegetation buffer zones should be established between existing, intensively cultivated terrestrial areas and the new waterbodies. The vulnerability of particular sediments to nutrient leaching, based on soil sorption properties and the extent of revegetation, should be identified so that post-harvesting landuses of cutaway peatlands can be designated in an appropriate, site-specific manner.
- Lakes created by reflooding areas of industrial cutaway peatland are new, essentially artificial phenomena and no true basis in experience exists on which to predict their development. In view of the considerable timescale involved in ecosystem establishment and stabilisation, it is essential that monitoring of the existing cutaway peatland lakes continues in order for long-term trends to be assessed.

Photo 3: The industrial cutaway peatland landscape in Ireland, pre- and post-flooding.

Acknowledgements

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Related Web Resources

http://www.nuigalway.ie/eci/report/higginsreport.pdf (non-technical research report) and http://www.loughbooraparklands.com (Lough Boora Parklands official website)

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Table 1: General characteristics of four artifical lakes, Finnamore, Tumduff, Turraun and Clongawny, created on harvested cutaway peatlands in Ireland.

	Year created	Size(ha)	Mean depth (m)	Sediments	Inflows	Post-flooding management
Finnamore	1996	4.8	1.5	Silty clays, gravel, glacial till	Piped inflow, Precipitation,	Environs landscaped & seeded; invertebrates, fish & aquatic plants introduced
Tumduff	1995	6	1	*Phragmites* peat	Piped inflow, Precipitation,	Environs seeded,trees planted
Turraun	1991	60	0.5	*Phragmites* peat, shell marl	gw springs, Precipitation,	Environs seeded,trees planted
Clongawny	2001	12	1	*Sphagnum* & woody fen peat	Precipitation, surface runoff	None

Table 2: Physico-chemical and nutrient characteristics of Finnamore, Tumduff, Turraun and Clongawny cutaway lakes. Values shown are mean from August 2001 to September 2004 (n=53).

	pH	Alkalinity (mg $CaCO_3$ l^{-1})	Colour (Pt. Co.)	Turbidity (NTU)	TP[1] (mg l^{-1})	DIN[2] (mg l^{-1})	Chl-a[3] (mg l^{-1})	Trophic status[4]
Finnamore	8.1	181	19	1.9	12.2	1.56	5.2	Mesotrophic
Tumduff	8.1	127	74	2.4	15.6	0.24	3.3	Mesotrophic
Turraun	8.2	140	48	6.4	26.7	0.15	12.7	Mesotrophic-eutrophic
Clongawny	4.6	1.6	159	12.9	39.1	0.09	52.5	Eutrophic-hypertrophic

[1]TP: total phosphorus; [2]DIN: dissolved inorganic nitrogen; [3]Chl-a: chlorophyll-a; [4]Based on classification of Vollenweider & Kerekes (1982)

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Working Group News

"Aquatic Invasions" e-journal is established by SIL Working Group on Aquatic Invasive Species

SIL Working Group on Aquatic Invasive Species has established a new European e-journal "Aquatic Invasions". Aquatic Invasions is a rapid on-line journal focusing on biological invasions in European inland and coastal waters and potential donor areas of aquatic invasive species for Europe. The journal provides the opportunity for timely publication of first records of biological invaders for consideration in risk assessments and early warning systems. Also, the journal provides opportunity to publish relevant technical reports and other accounts not publishable in regular scientific journals. Aquatic Invasions is a part of the developing European early warning system on aquatic invasive species, with an important service of protection of author's rights on primary geo-referenced information on species records. The first issue of AI is available online at http://www.aquaticinvasions.ru . Manuscripts relevant to inland waters invasions can be submitted to Dr Vadim E. Panov (rbic@zin.ru) and manuscripts relevant to invasions in coastal waters to Dr Stephan Gollasch (SGollasch@aol.com).

Vadim E. Panov
Zoological Institute of the Russian Academy of Sciences
Universitetskaya nab. 1
199034 St.Petersburg
Russia
E-mail: rbic@zin.ru

Announcements

9th European Workshop On Physical Processes In Natural Waters

Contributed by Andrew Folkard, Lancaster University, United Kingdom, a.folkard@lancs.ac.uk; Alfred Johny Wüest, EAWAG, Kastanienbaum, Switzerland, alfred.wueest@eawag.ch; Bertram Boehrer, UFZ, Magdeburg, Germany, Bertram.Boehrer@ufz.de; and Sally MacIntyre, UC Santa Barbara, California, USA, sally@icess.ucsb.edu

In the first week of September 2005, an enthusiastic group met in Lancaster, England to present and discuss work on physical limnology and a wide range of cognate areas. This was the ninth in this series of workshops that have been held at locations throughout Europe since the first in Kastanienbaum, Switzerland in 1996. The intention of the workshops is to provide a forum for scientists to exchange ideas and discuss ongoing research on topics related to physical processes in inland and coastal waters. A key aspect of the workshops is that, in each half hour time slot, equal time is given to presentation and to subsequent discussion. This allows for a lively, thorough and uninhibited exchange of views and ideas.

This year forty-four participants attended the three days of the workshop, and sessions were held on internal waves and mixing, riverine and shallow waters, atmospheric influences, biogeochemical-physical interactions and mixing and cold water. Particularly valuable were the invited presentations given by Hans van Haren (Royal Netherlands Institute for Sea Research), Tom Rippeth (School of Ocean Sciences, Bangor, Wales), Heidi Nepf (MIT) and Sally MacIntyre (University of California, Santa Barbara), which offered excellent springboards for discussion of their and others presentations.

A notable element of the majority of the presentations was the importance of coupling of the physical processes that were their primary focus with biological, chemical and geological processes that co-occurred. In some cases, acknowledgement of this coupling took the form of motivation for studies that were then executed with a purely physical focus, whereas in others it formed an integral element of the science.

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Working Groups of SIL and their Contact Persons as of May 2006

Ancient Lakes

Dr. Oleg A. Timoshkin, Chairperson
Limnological Institute
Siberian Branch
Russian Academy of Sciences
Ulan-Batorskaya, 3
P.O. Box 4199
664033 Irkutsk
RUSSIA
Phone: 3952 42 82 18; Fax: 3952 46 54 05
E-mail: tim@lin.irk.ru

Aquatic Birds

Dr. Joseph J. Kerekes, Chairperson
Environment Canada
Canadian Wildlife Service
45 Alderney Drive
Dartmouth, N.S. B2Y 2N6
CANADA
Phone: 902 426-6356; Fax: 902 426-4557
E-mail: joe.kerekes@ec.gc.ca

Aquatic Invasive Species

Dr. Vadim Panov, Chairperson
Zoological Institute of the
Russian Academy of Sciences
Universitetskaya Nab. 1
199034 St. Petersburg
RUSSIA
Phone: 7 812 3233140; Fax: 7 812 3282941
E-mail: rbic@zin.ru
Web: http://www.zin.ru/rbic/projects/sil_wgais/

Aquatic Microbial Ecology

(Formerly: Microbial Activities and the Carbon Cycle in Fresh Waters)
Dr. Meinhard Simon, Chairperson
Inst. of Chem. & Biol. of the Marine Env.
University of Oldenburg
P.O. Box 2503
D-26111 Oldenburg
GERMANY
Phone: 49 441 970 6361;
Fax: 49 441 798 3438
E-mail: m.simon@icbm.uni-oldenburg.de

Aquatic Primary Productivity (GAP)

Dr. John Beardall, Co-chairperson
School of Biological Sciences
PO Box 18, Monash University
Wellington Road
Clayton, VIC 3800
AUSTRALIA
Phone: +61 3-99055611; Fax: +61 3-99055613
E-mail: John.Beardall@sci.monash.edu.au

Dr. Vivian Montecino, Co-chairperson
Universidad de Chile
Faculltad de Ciencias
Dept. de Ciencias Ecologicas
Las Palmeras # 3425
Casilla 653, Santiago
CHILE
Phone: +56 271-2049; Fax: +56 272-7363
E-mail: clorofil@uchile.cl

Biodiversity

Dr. Hiroya Kawanabe, Chairperson
Lake Biwa Museum
1091 Oroshimo, Kusatsu
Shiga 525-0001
JAPAN
Phone: 81 775 68 4812; Fax: 81 775 68 4848
E-mail: kawanabe@LBM.GO.JP

Biological Monitoring

Chairperson to be determined.

Conservation and Management of Running Waters

Dr. Philip J. Boon, Chairperson
Scottish Natural Heritage
2/5 Anderson Place
Edinburgh EH6 5NP, Scotland
UNITED KINGDOM
Phone: 44 131 446 2412; Fax: 44 131 446 2405
E-mail: phil.boon@snh.gov.uk

Ecohydrology

Prof. Maciej Zalewski, Co-Chairperson
International Centre for Ecology
Polish Academy of Sciences
90-364 Lodz Tylna St.3
POLAND
Phone/Fax: (+ 48 42) 681 70 07
E-mail: sekretariat@mcepan.lodz.pl

Dr. Richard D. Robarts, Co-Chairperson
National Water Research Institute
11 Innovation Blvd.
Saskatoon, SK S7N 3H5
CANADA
Phone: 306 975-6047; Fax: 306 975-5143
E-mail: richard.robarts@ec.gc.ca

Macrophytes

Prof. Jacques Haury, Chairperson
Agrocampus Rennes
Lab. Ecology and Crop Protection Unit
UMR INRA-Agrocampus Rennes
Biology, Ecology & Quality
of Inland Water Bodies
65, rue de Saint-Brieuc, CS 84215
F-35042 Rennes Cedex
FRANCE
Phone: +33 02 23 48 55 39
Fax: +33 02 23 48 51 70
E-mail: Jacques.Haury@agrocampus-rennes.fr or Jacques.Haury@rennes.inra.fr

Periphyton of Freshwater Ecosystems

Chairperson to be determined.

Physical Limnology

Dr. Sally MacIntyre, Chairperson
University of California-Santa Barbara
Marine Science Institute
Santa Barbara, CA 93106-6150
USA
Phone: 805 893-3951; Fax: 805 893-8062
E-mail: sally@icess.ucsb.edu

Plankton Ecology (PEG)

Dr. Miquel Lürling, Chairperson
Aquatic Ecology and Water
Quality Management Group
Wageningen University, P.O. Box 8080
6700 DD Wageningen
THE NETHERLANDS
Phone: +31-317-482689 or 483898
Fax: +31-317484411
E-mail: miquel.lurling@wur.nl

Saline Inland Waters

Dr. Brian V. Timms, Chairperson
School of Environmental and Life Sciences
University of Newcastle
Callaghan, NSW 2308
AUSTRALIA
Phone: 61 2 4921 7229; Fax: 61 2 4921 6914
E-mail: brian.timms@newcastle.edu.au

Wetlands

Dr. Brij Gopal, Chairperson
School of Environmental Sciences
Jawaharlal Nehru University
New Delhi 110067
INDIA
Phone: 91 11 617 2438; Fax: 91 11 616 5886
E-mail: brij@nieindia.org

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Two of the invited speakers – Hans van Haren and Tom Rippeth – are oceanographers working mainly in shallow seas and presented an oceanographic perspective on internal waves, stratification and mixing, emphasising the crucial importance of physical mixing processes for plankton population dynamics and carbon budgets. This provided a fascinating comparator for studies of the same phenomena in lakes, which reflected these linkages and in addition demonstrated the importance of internal waves for inter-basin exchange (Umlauf, Rao) and littoral zone mixing (Lorke, Hofmann).

A number of talks presented new results from numerical modelling studies of internal waves, focussing in particular on the mixing caused by their breaking as they shoal (Lamb, Vlasenko, Stashchuk). These demonstrated significant recent improvements in models' ability to capture the full physics of these processes, which are central to accurate quantification of lake mixing.

Sally MacIntyre's invited talk provided an excellent summary of our knowledge of the implications of hydrodynamic mixing and internal wave processes for biogeochemistry and in particular focussed on the importance of spatial and temporal variability of this linkage. Taking up this theme, a number of other speakers reported work which highlighted the importance of short term atmospheric forcing (Bormans) and spatially variable physical structure of the water column (Persson) in determining plankton distributions. In particular, our increased understanding of the often complex influence of fluvial inflows (Boehrer, Finger, Kay) was demonstrated.

Several presentations focussed explicitly on interactions between hydrodynamics and ecology. These considered primarily flow-vegetation interactions and impacts of mixing on the plankton. Heidi Nepf's invited talk provided a comprehensive overview of current understanding of the physics of flow in aquatic vegetation, and its similarities and differences with terrestrial canopy flow, which has been more fully studied. Further presentations reported recent numerical (Dijkstra), flume (Maltese, Folkard) and field studies (Ciraolo, Lovstedt) in this area. Key points requiring more research that emerged were the importance of spatial heterogeneity in vegetated canopies in determining their impact on flow and transport, and the importance of their ability to affect stratification (by shading or attenuating wave fields) in addition to their hydraulic drag function.

New understanding of the influence of hydrodynamics on sediment processes and lake chemistry were also reported by several speakers. Talks in this area spanned the influences of groundwater (Sanchez) and fluvial inputs (Boehrer, Finger, Kay), internal mixing (Miller, Singleton) and atmospheric forcing (Soler), demonstrating that much remains to be understood about the complex coupling of physical processes to these aspects of limnology. Prandle presented a longer term view of the implications of modified water cycle and fluvial dynamics on estuarine function.

Presentations on atmospheric influences on lakes focussed on current limitations in our understanding of the effect of lake-atmosphere interactions on lake dynamics. The importance of limited fetch on transfer coefficients (Jones), the restructuring of the wind profile at the land-water transition (de Marchis) and the complex influence of weather variations on lake stratification (Closter) and bed sediment re-suspension (Serra) were all discussed. Implications of variability if surface energy fluxes on lake circulation were addressed by (Ibrayev). New methodologies presented included 3D tomography, for determining basin-scale stratification (Falourd) and a novel strategy for estimating bathymetry of large basins which also included remotely sensed data (Zola).

A number of studies of unusual mixing and stratification phenomena observed in specific lakes were presented, including double diffusive staircase formation driven by temperature and CO_2 concentrations in Lake Nyos (Wuest), coherent, cold filamentous structures in the mixing layer (Ozen), high vertical mode internal waves (Ilmberger), a gyre in quasi-solid body rotation driven by an internal surge in a small lake (Golosov) and changes in mixing due to freshwater influxes in Lake Van – the world's largest soda lake (Kaden).

Finally, two presentations reported new efforts at modelling all these coupled phenomena in a coherent fashion (Terzhevik, Deydier-Stephan).

The tenth workshop in this series will be held in Granada, Spain in late June 2006. Anyone interested in attending should contact Dr. Francisco Rueda (fjrueda@ugr.es) or see http://www.ugr.es/~iagua/PPNW10.htm.

Book Reviews

Limnology In Developing Countries Volume 4

Edited by B. Gopal and R.G. Wetzel
244 + viii pp., 2004. A SIL book printed by International Scientific Publications, New Delhi, India. ISBN: 81-86047-23-9

I approached this review with a mix of curiosity, nostalgia and apprehension. As a past resident of a developing country, Zimbabwe (where I was born), and now a resident of a so-called developed country, Australia (where I have lived for some 29 years), I was curious to compare my experiences as a limnologist in both regional categories with those of other limnologists. Frankly, I had not found much qualitative difference between limnological knowledge and understanding in Zimbabwe and in Australia and I was interested to know how typical my experience was. My feelings of nostalgia were aroused by memories of limnological studies in the biologically diverse tropical waters of Africa, crystallised for me in the unforgettable call of the African Fish Eagle and the unmistakable grunting of hippos at night. But, perhaps most powerful of all, I was apprehensive that I would read of waters that were once relatively pristine and valued for that, which have latterly become polluted, or over exploited by well-intentioned developers with high engineering skills and laudable economic motives. Unfortunately, too many such developers have little awareness of the sensitivity of the living ecosystems they

seek to exploit and of the extent to which the continued existence of the remarkably thin mantle of life surrounding the Earth ultimately depends on the healthy resilience of such systems.

South Africa

The account given of "Limnology in South Africa: Past and Present Status and Future Needs" by Brian Allanson is exemplary. It is both thorough and thoughtful, covering an intensity and extent of limnological studies that could stand comparison with that of any 'developed country' in terms of both quality and relevance for the ongoing management of the country's water resources. The account demonstrates a maturity of understanding and application of knowledge to management of water resources across a subcontinent of varying climate and ecology. This is also reflected in the bureaucratic structures of government that span the related and highly relevant endeavours of research, conservation and utilisation that contribute to overall management of the resource.

The wide range of freshwater bodies in South Africa is well represented in Allanson's account. These include two natural inland lakes (Fundudzi and Sibaya), a number of coastal lakes formed by the transgression of the sea at the end of the last Ice Age, and some 520 large dams (i.e., dams which are 15m or more high, as defined by the World Commission on Dams), which have been constructed to store water for subsequent use, independently of the highly variable rainfall. There is also a wide range of wetland systems, such as the extensive deltaic system of the Okavango Swamps in neighbouring Botswana, on the one hand, and a number of relatively small ephemeral systems, known locally as vleis and pans, on the other. River flows are highly variable, but remain important as a means of conveying water into naturally arid areas. These features closely parallel the situation in Australia and it is remarkable how many of the authors listed in the references have drawn on, or contributed to, studies in both countries.

Investigations of the limnological phenomena and the nature of the biota, which characterise this wide range of ecosystems, are provided in sufficient detail for the reader to obtain a good understanding of the structure and function of these systems backed by a selection of references to an extensive body of publications, from which further detail may be obtained. These accounts are complemented by an interesting and thought provoking review of the significant human impacts on southern African landscapes, including afforestation, river regulation, interbasin transfer and "pollution" of fresh waters, including invasion by alien plants and animals. Increasing experience and analysis of these impacts clearly provide an informed basis for sustainable management of the water resources on which the future of the sub-continent depends.

Zimbabwe

Limnological studies in land-locked Zimbabwe were initiated in the 1950s, the earliest publications in the list of references being those of fisheries biologists Ian van der Lingen from Harare (van der Lingen 1960) and Derek Harding from Zambia (Harding 1961). Prior to that, scientific interest in the country's freshwaters appears to have been focussed on collections of flora and fauna, most notably fish. Subsequent growth in knowledge and understanding of freshwater ecosystems from the 1960s to the present is outlined in "Limnology of Zimbabwe" by Rudo Sanyanga and Lindah Mhlanga, their account being set in the context of the country's geography, climate and natural resources.

As in neighbouring South Africa, much of the impetus for limnological research was the need to monitor, understand and manage artificial reservoirs, which were reported to number 10,747. These ranged in surface area from less than a hectare (mostly catchment dams on farms) to Lake Kariba, which was created by a dam across the Zambezi River and which impounds 160,000 m^3 with a surface area of 525,000 ha. A graph of the rate of dam construction from 1900 to 1980 demonstrates a remarkable exponential growth in these, particularly from the 1950s. Most of these reservoirs were constructed to provide water for agriculture or urban and industrial use, with the notable exception of Lake Kariba, which was constructed to provide hydroelectric power. Of the rest, 80% of abstracted water is used in agriculture, 9% by industry and mining and 11% in urban settlements. However, the 69% of the population who live in rural areas are mostly dependant on groundwater for reasonably reliable supplies of usable water, since many of the surface water bodies, including the rivers, are polluted and unreliable.

Sanyanga and Mhlanga provide clear and concise accounts of the quite extensive studies carried out on Lake Kariba and on Lake Chivero (formerly Lake McIlwaine), which was constructed in 1952/53 to provide water for the capital city, Harare. The creation of Lake Kariba is particularly noteworthy, since it provides a significant example of a major modification of natural systems with the intent of furthering
the economic and social development of a hitherto relatively undeveloped country on a national and even international scale. Plans to deal with the inevitable impacts on local ecosystems and social structures were largely secondary and somewhat *ad hoc*, as exemplified by the response to the rapid spread of the alien weed, *Salvinia* and the "Operation Noah" campaign to rescue wild animals that were in danger of being drowned by the rising waters of the newly forming lake.

However, studies of the limnology of the new lake were commenced as it filled and developed lacustrine conditions. These are briefly described by Sanyanga and Mhlanga and set out in more detail in the book on Lake Kariba by Balon and Coche (1974), to which they refer. These studies were accompanied by the development of exploitable fisheries on the lake which produces some 90% of the country's fish production.

The limnology of Lake Chivero provides a classic example of the impact of a city on its basic water source, when the city is placed within a major portion of the catchment of that water source. The lake was formed by a dam across the Manyame River. The presence of the city in the catchment has resulted in its significant nutrient enrichment, the main factor being the inflow of effluent from the city's sewage treatment works down the Mukuvisi River, a tributary of the Manyame, which enters upstream of the dam. This has resulted in continuing severe blooms of toxic cyanobacteria and the periodic development of excessive growths of the floating alien water weed, *Eichhornia crassipes* (water hyacinth).

The account of the limnology of Zimbabwe concludes with a thoughtful outline of perceived gaps in knowledge, largely resulting from an understandable focus on Lakes Kariba and Chivero. In particular, Sanyanga and Mhlanga point out the need for more studies on the ecology of riverine systems and the management of potential pollution problems. They also identify some important needs in relation to the collection and analysis of water quality data and appropriate catchment controls in view of the continuing growth in demand for reliable supplies of water and in recognition of the finite nature of the resource.

Turkey

"Limnology in Turkey' by Nuray (Emir) Akbulut provided an interesting contrast with the preceding accounts of limnology in South Africa and in Zimbabwe. The differences in topography, geography and climate were immediately apparent, but there were also other factors which would affect the nature of the limnological studies required for the management of the country's inland waters. First, the range of landforms and types of natural water bodies in Turkey were different from those in southern Africa. Second, there were profound differences in the breadth and depth of understanding of the biology and limnology of the inland water bodies. Yet there were very similar social imperatives with respect to the needs for well-informed, sustainable management of water resources in the long-term interest of the welfare of the nation and its people.

In contrast with southern Africa, Turkey has some 200 natural lakes with a total surface area of about 5,000,000 ha and 794 reservoirs with a total surface area of the order of 150,000 ha. The Ataturk Dam across the Euphrates River in the south-eastern part of the country impounds water with a total surface area of 817 km^2 and a volume of 48.5 km^3 and is one of the 10 largest dams in the world. Since the Euphrates and Tigris rivers drain into Iraq and Syria, where they are important sources of water, such developments have required consultation leading to development of protocols and agreements between these neighbouring countries. However, these have proved difficult, though progress continues to be made.

Investigations of the inland waters of Turkey have focussed more on establishing the nature of their flora and fauna than on developing an understanding of the physico-chemical limnology. However, physical and chemical parameters for some of the important lakes in Central Anatolia were recorded in the last couple of years of'the last century and investigations of the water quality of some of the major river systems have now commenced. It is acknowledged that such investigations need to be intensified and continued so as to provide a stronger basis for informed management of the nation's water resources. This is borne out by evidence of pollution from a variety of chemicals used in agriculture, industry and domestic situations leading in some cases to bioaccumulation in ecological food webs. Such studies should include some of the saline waters that provide important habitats for water birds and a number of rare and endangered species.

Akbulut concludes his account of the limnology of Turkey with a list of 10 conclusions and recommendations which focus on the need for more monitoring of the country's water bodies leading to clear and comprehensive descriptions of their ecological and social assets. There is a need for research to provide a firm basis for management of the nation's water resources that is balanced and sustainable. Information and understanding gathered in this way should then be shared and communicated through a variety of internal workshops and training programs, reinforced by participation in appropriate international interactions as opportunities occur.

The Sultanate of Oman

The final article in Volume 4 of "Limnology in Developing Countries" consists of an account by Reginald Victor of the current status of limnology in the Sultanate of Oman on the south-eastern end of the Arabian Peninsula. The country is arid or semi-arid and fresh water is a precious commodity. The introduction of desalination technology has alleviated some of the pressure for reliable supplies of water for human settlements but three important forms of land use: oil and mineral exploration, agriculture, and urban development have potentially adverse impacts related to water. Thus, production water from oil wells is difficult to dispose of, modern agricultural technology has caused salinisation and rapid urban growth has increased demand for fresh water.

In Oman, a *wadi* (plural – *wedian*) is a seasonal river, flowing only for some months when it is manifested as a "mosaic of habitats", which are structured and restructured by tranquil or catastrophic flood events. Water is also harvested from natural spring-streams termed *aflaj*. Reservoirs, ponds and pools are present, but there are no large natural freshwater lakes. Retention reservoirs in the mountains are often eutrophic as a consequence of contamination by faecal matter from goats. Recharge reservoirs in the foothills improve groundwater recharge but often receive sediment loads from upstream. There are only a few natural ponds in Oman, but temporary ponds can fill briefly with rainwater. Groundwater ecosystems have been studied only recently, primarily with the intent to protect them from pollution from sewage effluent and other aquatic waste waters.

There has been considerable interest in studies of biodiversity in freshwater ecosystems, primarily to compile lists of species from a taxonomic perspective. Many gaps remain in terms of both taxa and ecosystems. Not surprisingly, in the absence of such information there are a number of threats from uninformed human interference with aquatic ecosystems and from the unthinking introduction of potential weeds and animal pests. Aquatic habitats are also being modified to suit human objectives or are being subjected to pollution.

Such perturbations are likely to persist in the absence of understanding and knowledge about possible unwanted impacts. The key to the prevention of these is the establishment of education and training courses on limnology and water management. These need to be accompanied by structured research programs to address important gaps in understanding so that management and conservation of water resources in the Sultanate of Oman may be put on a sound progressive basis.

Some Final Comments

Science is a truly international endeavour and water is universally necessary for the continuation of life as we know it.

Territorial boundaries between nations should not be barriers to the sharing of water resources and knowledge and experiences of their management. Yet this is often the case! Indeed, it is predictable that the continuing growth in human population and increasing developments in the skills of managing natural resources will lead to increasing competition for supplies of fresh water.

The series of publications on limnology in developing countries by the International Association of Theoretical and Applied Limnology provides a laudable example of an effective means of formerly sharing information about the science and use of water among scientists who can benefit directly and who can act as conduits for sharing such benefits among the nations to which they belong. As the series continues, it is likely that the distinction between "Developing" and "Developed" countries will become increasingly blurred, though the basic distinction in relation to national wealth is likely to remain. This situation will continue to challenge humankind and emphasises the need, and indeed, the responsibility to continue this series of publications.

Finally, the enormous debt the science of limnology owes to Robert Wetzel for his contribution to the science is demonstrated yet again by his co-editorship of this series prior to his untimely passing. It is gratefully acknowledged!

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David Mitchell
Charles Sturt University
Australia
dmitchell@csu.edu.au

The Lakes Handbook, Volume II. Lake Restoration and Rehabilitation

Edited by O'Sullivan P.E. and Reynolds C. S. (2005). Blackwell Science Ltd. Oxford, UK. 560 pp. Price £125.00. ISBN 0-632-04795-X

Volume II of the Lakes Handbook sets before itself the admirable goal of providing "an up-to-date overview of the application of ecologically sound approaches, methods and tools using experience gained around the world for an understanding of lakes and their management …". Divided into five sections (General Issues, Regional Studies, Human Impact on Specific Lake Types, Lake and Catchment Models, and Legal Frameworks) this book achieves this goal in many respects, but falls short in others. Certainly there is a niche for this type of book in the limnological literature - although there are a number of lake restoration and management books written primarily for a less scientific audience, few exist that summarize the complexities of these endeavours from more global and ecological perspectives.

The General Issues section (which may have been more appropriately titled "Societal Issues") makes its contribution with two chapters that deal primarily with the human valuation of lakes. This topic is generally not well-covered for limnological audiences and its inclusion by the editors is an excellent choice for a restoration text. These chapters give a detailed, somewhat theoretical, social science perspective on human perceptions of lakes and our anthropogenic impacts – information that is important for our understanding of the couplings and feedbacks between humans and lakes. However, one aspect lacking was any real discussion of the notion of ecosystem services as they apply to lakes. Although the concept's utility is somewhat controversial among social scientists, the valuation of ecosystem services has received considerable attention of late and this section would be improved by its inclusion.

The second and third sections of this volume offer useful reviews of regional lake types as well as their associated anthropogenic impacts. The chapters covering our much-neglected tropical lakes and reservoirs are particularly insightful as is the chapter on Lake Washington, the latter not regional, but a nice summary of research that illustrates the interplay between policy, management, and science. Issues associated with eutrophication are deservedly emphasized in essentially all the papers in these sections given the global nature of this problem. Stressors like acidification, metal contamination, and exotic species are mentioned as well, but the reader seeking a greater coverage of human impacts may want to look elsewhere. Given the individual nature of the contributions and this common theme there is some redundancy among these chapters in terms of introductory material on eutrophication - with most authors opting for inclusion, this process is very well-defined.

The last two sections are dedicated to modeling and policy. The modeling section provides a good overview of models pertinent to lake function and restoration, again with an emphasis on their application to enriched systems. On the whole, models are very well-described with accompanying consideration of the processes affecting model inputs, but less attention is given on model comparison, choice, or application. The policy chapters are welcome additions to a text dealing with restoration and rehabilitation. They present useful summaries of legislation from a number of different regions which allow easy comparisons, but with the exception of a brief discussion related to developing countries there is little advice to guide limnologists in how to better communicate our science and help effect the changes in policy that are desperately needed in many regions.

Overall, the review of literature in the chapters was very thorough, particularly with respect to the inclusion of seminal papers and many lesser known European citations, however many recent papers on various topics were not as evident. Despite its limitations, *Volume II: Lake Restoration and Rehabilitation* accomplishes its goal of providing an overview of approaches, methods and tools for understanding lakes and their management and deserves a place on limnological bookshelves. To spend a bit more time off the shelf and in the hands

of students and researchers, this book might have increased its coverage of different stressors and even further enhanced its modeling and policy toolboxes. The editors should be commended for their recognition of the need for this collection of research.

Jim Rusak
Trout Lake Station,
Center for Limnology
University of Wisconsin-Madison, USA

Phosphates In Sediments

Proceedings of the 4th International Symposium, Carmona (Spain), 9-12 September 2003. L. Serrano and H.L. Golterman (eds.) 202 pp., 2005, paperbound. Backhuys Publishers. ISBN 90-5782-154-0. €88

The book "Phosphates in sediments" is a collection of papers presented at the 4th International Symposium on phosphate in sediments held at Carmona (Spain) from 9 to 12 Sept. 2003. The book opens with a preface, which briefly documents the history of the symposia and provides a concise description of the session themes, which form the basis for the organization of the book.

The book, which contains interesting data and a wealth of information, is organized into six sections, preceded by an editorial written by Golterman whose career in limnology spans 50 years. This article, with a truly engaging title *Chemistry and Limnology: A "Marriage de Raison"*, lists problems (just like the title promises) encountered in the multidisciplinary and largely empirical field of limnology, particularly in the investigations of sediment-water interaction. Somehow, however, I failed to get out of it why this marriage of limnology and chemistry is a must for its offspring. The challenges and contentious issues, advanced in this paper, set the stage for this book.

The introductory article is followed by the first section whose topic is exchange and release processes. The first article of this section compares sampling techniques and equilibration times of methods used to determine the porewater composition, one of the key factors regulating sediment-water exchange. Two contributions assess efficiency of phosphate and metal removal by sediment in a small-scale constructed wetland. The importance of microbial influence on nutrient (P and S) dynamics, as related to the type of the sediment org-C, is discussed in one paper, which contests current models of P-cycling. Importance of microbial processes on P release through its influence on the breakdown of organic matter is also discussed by another contribution, which stresses the importance of biological activity on the chemical equilibrium between sediment and overlying water in highly eutrophic waters of coastal lagoons of Spain. Lastly, a comparison of various factors affecting the phosphate adsorption of sediments under laboratory conditions and the problems associated with estimating P-binding capacity of sediments is discussed. The influence of salinity and sediment composition on P-binding capacity in an estuarine environment is also discussed in a paper from the last section of the book.

The second section entitled *Vertical distribution in sediment/Composition/ Availability* contains several short abstracts and a paper on the spatial and temporal variability of water and sediment P as it relates to land use and sediment P transport in cascading reservoirs on the Paranapanema River in Brazil.

Information on the mobility and biological availability of sediment P is a valuable tool in lake management. Some forms of P are better predictors of its mobility and bioavailability than others. Phosphorus speciation, which is discussed in the *Methodology* section, is valuable for assessment and quantification of P forms. The contributions in this section evaluate utility of bioassays and various extraction procedures for determination of various forms of P, particularly as it relates to its short and long term bioavailability.

Algal decomposition and the importance of phytate to the pool of bioavailable P in sediments is discussed in the *Transformation* section, which also examines fluvial processes and sediment transport in three South American rivers. A paper on potential P remobilization, resulting from decreasing acidity in an acid mine pit lake, highlights the importance of metal-organic complexes for P adsorption in sediments.

The *Transport and Fluxes* section covers topics related to the importance of in-lake processes (e.g., diffusive flux, sedimentation) for P dynamics during late stratification and early mixing transition, impact of macrozoobenthos on pore water heterogeneity, and nutrient dynamics in streams draining agricultural catchment in Argentina.

The last section discusses how some macrophyte species adapted to P-limiting conditions are capable of utilizing sediment P even from less labile fractions through symbiosis with mycorrhizal fungi or exuding organic acids present in their roots.

Overall, this book is an exhaustive review of current research on sediment phosphate biogeochemistry. It is not intended for a general audience, but is a valuable reference material for biogeochemists, limnologists and other aquatic scientists involved in studies of nutrient dynamics in aquatic ecosystems. I would strongly recommend it as an acquisition for a library of any institution involved in research and management of water resources.

Tatiana Mayer
National Water Research Institute
Environment Canada, Canada
E-mail: tanya.mayer@ec.gc.ca

Lake Hiidenvesi - Studies On a Clay-turbid and Eutrophic Multi-basin Lake

Edited by S. Repka and coordinated by Jukka Horppila 232 pp., 2005 *Advances in Limnology 59*, E. Schweizerbart'sche Verlagsbuchhandlung,Germany
ISBN 3-510-47061-3, € 54.00

This special issue summarises results from a comprehensive cross-institutional and multi-discipline five year study of the Finnish Lake Hiidenvesi - headed by Jukka Horppila, University of Helsinki. Included are 13 original papers by a number of authors and an introduction and summary, the latter two authored by the project leader. The topics included are diatoms in inlet streams (perhaps somewhat misplaced in this issue), in-lake studies of sedimentation and resuspension, bacterial production,

comprehensive studies on zooplankton and pelagic invertebrate predator abundance and behaviour, and fish abundance, distribution, behaviour and diet choice. Special focus is on the temporal variation on a diel scale of fish, fish diet and plankton. This study is of particular interest as it deals with trophic dynamics in a special lake type – clay-turbid lakes – and provides fresh and new insight into the growing body of studies of trophic dynamics of lakes. It shows how the higher background turbidity favors invertebrate predators (at least during part of the season), such as *Chaoborus* and *Leptodora* as they can use the turbidity as a refuge against their predators (fish), with cascading effects on zooplankton. For example, *Chaoborus* occurs in high densities in the water during daytime despite high densities of fish. It also shows how clay turbidity affects the fish community, disfavoring roach and enhancing cannibalism. Also the dynamics and mortality of fish during winter are studied in detail. The issue furthermore includes interesting studies on the role of emergent and floating-leaved plants as a refuge for zooplankton and lake stability, these plants being the dominant vegetation as the high turbidity prevents extensive growth of submerged macrophytes. It appears that emergent and floating-leaved plants act as a refuge for zooplankton and substrate for plant-associated forms with lower phytoplankton biomass as a result and that they further reduce resuspension, promote sedimentation and lead to reduced phosphorus release from the sediment. The study further deals with management aspects and it is concluded that biomanipulation is likely a less useful method to restore clay-turbid lakes than lakes where turbidity is dominated by phytoplankton. In summary, an interesting set of papers (well synthesized by Jukka Horppila) - worth reading for scientists interested in trophic dynamics, fish, plankton and management of lakes.

Erik Jeppesen
National Environmental Research Institute and University of Aarhus, Denmark

Calendar of Events

2006

54th Annual Meeting of the North American Benthological Society

4 - 9 June 2006
Anchorage, Alaska, USA

Additional information is posted on Society website: http://www.benthos.org

The 5th Conference of the Aquatic Birds Working Group of the International Association of Limnology "Limnology and Waterbirds 2006"

26 - 30 August 2006
Eger, Hungary

Web site: http://aquabird.ektf.hu/

Contacts:
Sándor Andrikovics
Department of Zoology
Eszterházy College of Education
H-3300 Eger Leányka utca 6., Hungary
Phone: 36 36 520-462; Fax: 36 36 520-462
E-mail: hidrobiosz@axelero.hu

Joseph Kerekes
Environment Canada
Dartmouth, Nova Scotia B3M 2X9
Canada
Phone: 1 902 426-6356;
Fax: 1 902 426-4457
E-mail: joe.Kerekes@ec.gc.ca

Speciation in Ancient Lakes - 4 (SIAL-4)

4 - 8 September 2006
Berlin, Germany

Contact:
Prof. Dr. Frank Riedel,
Chairman and organizer
paleobio@zedat.fu-berlin.de
Phone: +49-30-838-70-283

The Tenth International Symposium on Aquatic Oligochaeta

16 - 26 October 2006
The Institute of Hydrobiology
Chinese Academy of Sciences
Wuhan, China

Inquiries should be sent to both of the following email addresses:
ISAO2006@ihb.ac.cn and
ISAO2006@yahoo.com.cn

Official symposium website: http://www.ihb.ac.cn/isao2006/index.htm;
Mirror: http://www.inhs.uiuc.edu:80/~mjwetzel/ISAOBdir.html

Contact:
Dr. Hongzhu Wang, D.Sc.
Associate Professor
Institute of Hydrobiology
Chinese Academy of Sciences
Hubei, Wuhan 430072
People's Republic of China
Phone: +86 27 87647719
Fax: +86 27 87647664
E-mail: wanghz@ihb.ac.cn

2007

SIL2007 in Montréal.

Preparations for the next SIL Congress in Montreal are continuing. The local organizing committee is working towards an exciting scientific program with several special sessions as well as a series of excursions. Please visit the congress' website for more complete information and updates at http://www.uqam.ca/SIL2007

Symposium for European Freshwater Sciences 5 (SEFS5)

July 8-13, 2007
University of Palermo
Italian Association for Oceanology and Limnology
Freshwater Biological Association

SEFS is Europe's largest forum for freshwater science, which brings together scientists from numerous aquatic disciplines. Symposia are held every two years, in a different European city on each occasion. The series is coordinated by the Freshwater Biological Association (FBA) in collaboration with other limnological Associations of European countries. Congress' website at http://www.sefs5.it

Contact:
Luigi Naselli-Flores
Department of Botanical Sciences
University of Palermo
I-90123 Palermo, Italy
Phone: +39 091 6230244
Fax: +39 091 6238203
Email: sefs5@sefs5.it

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Chapel Hill, NC 27599-7431 USA
denisej@email.unc.edu
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SIL Officers

PRESIDENT

Gene Likens
Institute of Ecosystem Studies
Box AB
Millbrook, New York 12545, USA
E-mail: likensg@ecostudies.org

EXECUTIVE VICE-PRESIDENTS

Winfried Lampert
Max-Planck-Institut für Limnologie
Postfach 165
D-24302 Plön
Germany
E-mail: lampert@mpil-ploen.mpg.de

Brian Moss
School of Biological Sciences
Derby Building
The University of Liverpool
P.O. Box 147
Liverpool L69 3BX
Great Britain
E-mail: brmoss@liverpool.ac.uk

Chris Gordon
Department of Zoology
University of Ghana
Legon, Accra
Ghana
E-mail: cgordon@ug.edu.gh

ACTING GENERAL SECRETARY AND TREASURER

William M. Lewis, Jr.
Professor and Director
Center for Limnology
216 UCB, CIRES
Boulder, CO 80309-0216, USA
E-mail: lewis@spot.colorado.edu

EDITOR-IN-CHIEF

John R. Jones
Fisheries and Wildlife Sciences
School of Natural Resources
302 Natural Resources Building
University of Missouri
Columbia, Missouri 65211-7240, USA
E-mail: jonesj@missouri.edu

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